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16. Abstract (MAXIMUM 200 WORDS) Crew alertness and the incidence of sleep/wake cycle disruptions were evaluated aboard DEPENDABLE, a WMEC, throughout 32 consecutive days underway. This study was conducted during the implementation of crew reductions prescribed by the Paragon project. Thirty male crew members volunteered to participate in the study. Wrist activity monitors (WAMs) were used to document sleep/wake cycles and electroencephalography (EEG) techniques were used to measure alertness. Thirty participants wore WAMs throughout the study period, while a subset of 14 volunteers participated in short duration EEG alertness tests every three to five days. Alertness tests were administered within three hours of wakefulness from daily sleep. Participants were allowed to follow their daily routine prior to reporting for the wakefulness tests. Unremarkable weather conditions and low operational tempo characterized this patrol. However, analysis of sleep/wake cycles and EEG alertness tests revealed a 59 percent incidence of sleep/wake cycle disruption associated with high failure rates in the EEG alertness tests. Twelve out of the 14 EEG participants failed to maintain wakefulness in 50 to 100 percent of the tests. Participants working under non-rotating watch schedules (e.g., 0400-0800) exhibited consistent patterns of sleep and wake-up times with sleep duration rarely dipping below six hours. In contrast, participants exposed to frequent watch rotations showed disrupted sleep associated with the 0000-0400 and 0400-0800 watch schedule. Recommendations include the implementation of: a) a crew endurance education program to optimize the quality of crew rest; b) watch schedules that minimize sleep/wake cycle disruptions; c) the development of a system to reduce crew members' frequent rotation into the 0000-0400 or 0400-0800 watch schedules.			
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EXECUTIVE SUMMARY

United States Coast Guard (USCG) missions often require rapid response, sustained operations, rapid transitions from daytime to nighttime duty hours, extended duty hours, and the implementation of rotating work schedules. The interaction of operational tempo, extreme weather conditions, sea states, crew experience, and work schedules can combine to reduce crew endurance, performance, and safety. Crew endurance depends on the ability to optimize crew rest and on the prevention of shiftwork maladaptation (or shift-lag). Shift-lag and lack of sufficient energy-restorative sleep induce fatigue (sleepiness, low energy, and lack of motivation), performance degradation during duty hours, and ultimately reduced safety.

Two experimental Coast Guard (CG) programs, namely Paragon (Atlantic Area 210-ft WMEC operations) and Exemplar (Pacific Area 378-ft WHEC operations), are exploring the potential use of reduced crew complements aboard cutters. One major concern is that crew reductions may exacerbate crew fatigue, and ultimately, compromise safety. Here, we present the results of the Paragon fatigue evaluation study conducted aboard the cutter *DEPENDABLE* (WMEC-210 ft) during a patrol from Portsmouth, Virginia, to Halifax, Nova Scotia, Canada. The central objective of this evaluation was to determine whether crew members experienced fatigue levels that may result in reduced safety.

Volunteers were solicited from crew stations affected by reductions prescribed in the Paragon program. All experimental procedures were reviewed and approved by a certified Institutional Research Review Board. A total of thirty crew members volunteered to participate in the crew fatigue evaluation. All volunteers were in good physical condition, with no history of chronic health problems. All information collected was kept confidential. Volunteers were informed that they could withdraw from the study at any time without consequences of any type.

METHODS

ALERTNESS TESTS

We used electroencephalography (EEG) techniques to measure individual alertness over a 32-day period while the cutter was on patrol. Fourteen of the original 30 volunteers participated in this alertness evaluation. Tests were conducted every three to five days (as permitted by duty cycles) within three hours of wake-up time from normal sleep.

Participants were first instrumented with electrodes, connected to a portable EEG system, and asked to rest on a comfortable bed in a dark room. They were instructed to close their eyes and maintain wakefulness by mentally fighting the tendency to fall asleep.

In research and clinical sleep laboratories a similar test is used to determine the effects of sleep disorders on daytime sleepiness. Healthy individuals who sleep soundly and without disruption maintain wakefulness for at least 15 minutes. Individuals who experience consistent, but mild levels of sleep loss cannot maintain wakefulness beyond ten minutes. Research volunteers suffering from shiftwork maladaptation cannot maintain wakefulness beyond 8.2 minutes. Individuals with sleep disorders that induce severe daytime sleepiness usually fall asleep in less than ten and sometimes five minutes.

CREW ENDURANCE TESTS

TWENTY-FOUR HOUR SLEEP/WAKE CYCLES

Wrist worn activity monitors (the size of an oversize wristwatch) were used to document daily sleep/wake cycles. These devices were worn throughout the day, during work and sleep periods. Sleep/wake cycle data were collected from 25 of the original 30 volunteers (five discontinued participation) throughout 32 days. These data provide a daily history of activity and rest that permitted the assessment of sleep disruptions as a function of exposure to variable duty cycles and watch schedules.

RESULTS

Analysis of sleep/wake cycles and of EEG alertness tests revealed a high incidence of sleep/wake cycle disruption (59.0 percent) associated with high failure rates in the EEG alertness tests. Twelve out of the 14 participants failed to maintain wakefulness on 50 to 100 percent of tests.

Participants working under non-rotating, stable watch schedules (e.g., permanent 0400-0800 watch) exhibited consistent patterns of sleep and wake-up times with sleep duration rarely below six hours. In contrast, participants exposed to frequently rotating schedules showed disrupted and fragmented sleep associated with the 0000-0400 and 0400-0800 watch schedules. These work schedules disrupted the organization of 24-hour or circadian sleep/wake cycles and resulted in sleep loss and fatigue (commonly referred to as shift-lag). Recovery from this condition takes a minimum of three to four days of a consistent work rest schedule including: sleep per night (preferably seven or more consolidated hours), wake-up times, daylight exposure, and work schedules. However, symptoms of fatigue may be experienced for several days after the realignment of sleep and work schedules.

CONCLUSIONS AND RECOMMENDATIONS

Unremarkable weather conditions and low operational tempo characterized this patrol. However, evidence of fatigue, as depicted by high failure scores in the alertness tests and frequent disruption of sleep/wake cycles, was frequently detected. Based on this evidence, crew endurance levels during this low tempo patrol were considered less than optimal.

Operational situations involving increased tempo and deteriorating weather conditions are certain to exacerbate fatigue symptoms. The following recommendations are offered to improve endurance levels:

- 1) implementation of crew endurance education programs to optimize underway crew rest and to prevent shift-lag;
- 2) implementation of watch schedules that minimize sleep/wake cycle disruptions; and

- 3) development of a system to optimize the number of watch qualified personnel underway and to reduce crew members' rotations into the 0000-0400 or 0400-0800 watch schedules.